Application of Cotton Burr/Stem in Thermoplastic Composites

Sreekala G. Bajwa1, Dilpreet S. Bajwa2 and Greg A. Holt3

RESEARCH PROBLEM

Cotton gin waste (CGW) is a waste stream from a ginning operation that is rich in ligno-cellulosic fibers. Currently, there are no major commercial-scale applications for this material except for a small fraction that goes into either composting or is land applied. For a majority of gins across the country, CGW is a potential environmental liability and an expense to dispose of. Value-added products that can be made from CGW will generate a revenue stream for the ginners and producers while reducing the environmental burden. This study focuses on the application of plant fibers recovered from CGW in natural fiber reinforced thermoplastic composites. The thermoplastic composite material is investigated as an alternative to wood and wood polymer composites (WPC) for outdoor non-structural building applications such as deck boards, fences, landscaping products, and window and door components.

BACKGROUND INFORMATION

Thermoplastic composites reinforced with natural fibers offer a better choice for non-structural building materials subjected to outdoor weather conditions such as high moisture and temperature fluctuations. Wood is the most commonly used fiber filler in commercially available thermoplastic composites. (Bajwa et al., 2009a). With the ongoing focus on biomass energy, stagnation in the building sector and outsourcing of furniture industry, the U.S. is facing a growing shortage of wood fibers of desired quality. On the other hand, the U.S. cotton industry produces large quantities of cotton gin waste (CGW), which is rich in plant fibers. Some of these cellulosic fibers can impart desirable qualities to composites such as low specific gravity without large deterioration in strength. (Bajwa et al., 2009a; Bourne et al., 2007) Therefore, utilization of the cellulosic fibers from this agricultural waste stream can benefit the composite industry, agricultural industry, and the environment.

1 Associate professor, Biological and Agricultural Engineering Department, University of Arkansas, Fayetteville, Ark.
2 Research and Development manager, Greenland Composites, Greenland, Ark.
3 Research leader, USA-ARS, Cotton Production and Processing Research Unit, Lubbock, Texas.
Cotton gin waste contains cotton burrs or carpels, stems, leaves, motes, small seeds and some dirt. Approximately 40-70% of the cotton gin waste is made of cotton burrs and stems (CBS), with an additional 10-11% of motes or short fibers (Baker et al., 1994). During the ginning process, the CBS fraction can be easily separated from the rest of the waste stream if it is collected at the extractor (Holt et al., 2000). Preliminary research at the laboratory scale has shown great potential for using CGW as a fiber filler in thermoplastic composites (Bourne et al., 2007) and composition boards (Holt et al., 2009). However Bourne et al. (2007) used manual extrusion to manufacture the samples, and therefore, exhibited high variability in the composite properties. Also, the motes in the mixture created mixing problems. Therefore, this study was conducted with the objective to evaluate the potential of CBS as a fiber filler in thermoplastic composites through manufacturing using the extrusion process.

**RESEARCH DESCRIPTION**

A laboratory-scale experiment was conducted at the University of Arkansas Agricultural Experiment Station in Fayetteville. The experiments were designed to evaluate CBS as a potential fiber filler. Thermoplastic composite samples were manufactured with a twin screw counter-rotating extruder into approximately 1/4” by 1” profile. There were 4 fiber filler treatments that included CBS replacing the oak wood fiber used in a commercial WPC formulation by 0%, 25%, 50%, 70% and 100%. The 0% CBS is considered as the control. All composite materials used a total of 50% fiber filler, with the remaining being thermoplastics and other additives.

All fiber fillers were initially ground to a size distribution of 80-20 micron in size. The ground fibers were dried and mixed with the remaining ingredients (high density polyethylene and additives) in the required proportion, and then fed to the extruder. The extruded samples were water cooled and tested for physical properties such as specific gravity, water absorption, thickness swelling, coefficient of linear thermal expansion (CLTE) and mechanical properties such as flexural strength and modulus, hardness and nail withdrawal capacity. The ASTM standard D 1037-99 was used for testing mechanical properties. The CBS treatment means were compared against the control using Dunnett’s test, which was performed with JMP software, SAS Institute, Inc., Cary, N.C.

**RESULTS**

Once the extruder settings were optimized for the CBS fiber, the composite samples showed good surface appearance similar to that of the control. The specific gravity of all CBS treatments averaged at or slightly below unity. The 25% CBS treatment showed a significantly lower specific gravity than the control. A low specific gravity is preferred for certain building materials. The 24-hr water
absorption of the 50% and 75% CBS treatments was significantly higher than the control, while the thickness swelling of the 75% CBS treatment was significantly higher than the control. Lower values for both water absorption and thickness swelling are preferred for building materials. All treatments exhibited a similar coefficient of linear thermal expansion (CLTE).

A comparison of strength properties of composite samples showed that the flexural modulus of elasticity (MOE) of 75% and 100% CBS treatments were significantly lower than the control. However, modulus of rupture (bending strength), hardness and nail withdrawal capacity for all CBS treatments were similar to that of control. Although the CBS treatments with high substitution rates (75% and 100%) experienced some loss of flexural modulus, it is not a major concern for non-structural building applications. The only major concern was the increased water absorption of the 50% and 75% CBS treatments, which affects thickness swelling as well.

**PRACTICAL APPLICATION**

The outdoor non-structural building products are a growing area of application for thermoplastic composites. This study indicates that the wood fibers in the WPC products can be replaced by CBS by 25% without any degradation in the physical and mechanical properties tested here. At higher CBS substitution rates, water absorption was a major problem, which can be remedied by pre-treating the fibers with specialty chemicals/processes to make them water-phobic. Although there was a slight decrease in the flexural modulus, that is not a major concern since the material is used primarily in non-structural building applications.

**ACKNOWLEDGMENTS**

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**LITERATURE CITED**


**Table 1. Physical and mechanical properties of thermoplastic composites reinforced with different combinations of CBS and oak wood.**

<table>
<thead>
<tr>
<th>Treatment (%CBS)</th>
<th>Spec. Gr. (ratio)</th>
<th>Water Abs (%)</th>
<th>Thick Swell (%)</th>
<th>CLTE (mm/m°C)</th>
<th>MOE (MPa)</th>
<th>MOR (MPa)</th>
<th>Janka Hardness (N)</th>
<th>Nail Withdrawal Force (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.01</td>
<td>3.51</td>
<td>0.92</td>
<td>12.5</td>
<td>1644.29</td>
<td>15.34</td>
<td>5004.00</td>
<td>992.65</td>
</tr>
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<td>25</td>
<td>0.97&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.51</td>
<td>1.11</td>
<td>16.0</td>
<td>1424.70</td>
<td>14.68</td>
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<td>13.5</td>
<td>1289.50</td>
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<td>15.5</td>
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</table>

<sup>a</sup> Indicates a significant desirable difference from control.

<sup>b</sup> Indicates a significant undesirable difference in comparison to control (copyright: Bajwa et al., 2010).